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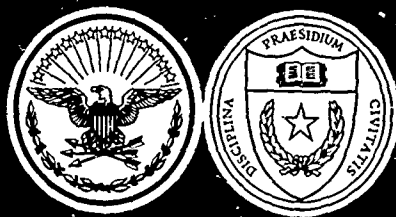
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DRL-A-246

17 February 1966

FINAL REPORT ON OFFICE OF NAVAL RESEARCH
CONTRACT Nonr-3579(01), PROBLEM 1:
STUDY MINE-HUNTING TECHNIQUES (NR 240-014)(U)

by

Lloyd A. Jeffress

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ACKNOWLEDGMENTS

So many people were involved in the work reported here that it would be impossible to list them individually as joint authors. Their work is acknowledged in the individual reports referred to in the present report.

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DRL is also grateful to the personnel of COMINPAC for the repeated assistance they have given us in the conduct of most of the exercises described in the present report, and to the officers and men of the various ships with which we have worked.

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Final Report on Office of Naval Research
Contract Nonr-3579(01), Problem 1

by
Lloyd A. Jeffress

I. HISTORICAL

The initial work which led to the present contract was conducted by DRL under Bureau of Ships Contract NObsr-52267, NE 051247-6, NE 051456-4 with funds furnished by the Office of Naval Research, Code '63. The work was suggested by Lt. Paul Newcomb of ONR, Code 463, and was concerned with extending his study of the clustering of mine contacts and of non-mine contacts. The early work involved employing tables of random numbers to represent the coordinates in a minefield of random contacts, such as those from gas bubbles, schools of fish, etc., and a table of the normal probability distribution to represent the variance of location of contacts from a bottom mine. Various false-contact densities were assumed along with a number of different values for the standard deviation of the sonar-navigational errors. After many sets of plots had been made, representing many passes of a mine-hunting ship through a minefield, it became apparent that much of what was being performed manually could be predicted from probability theory.

One of our first attempts to apply probability theory to the prediction of false clusters (chance groupings of random contacts) made the assumption that such clusters would follow a Poisson distribution. The predictions were compared with actual minefield data from Panama City and Norfolk, and showed that the actual data had more variance than the predicted. This fact led to the selection of Polya's distribution (negative binominal distribution) as a more appropriate function. It allows two degrees of freedom in the choice of parameters, where the Poisson distribution allows only one. When a value of the variance equal to twice the value of the mean was employed, the resulting function proved to fit the minefield data remarkably well. The Polya distribution was therefore employed in our later work. The Polya distribution yields the probability that the x th head will occur on the $(n+x)$ th toss of a coin, given the probability, p , of

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obtaining a head on a single toss. It is obtained by expanding $p^n(1-q)^{-n}$. By accumulating the probabilities so obtained, we find the probability of getting x or more heads (contacts) after n tosses (passes).

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II. STATISTICAL METHODS APPLIED TO MINE HUNTING

A. Parameters Involved in the Statistics of Mine Hunting

There are three basic parameters involved in predicting the effectiveness of multiple passes of a mine hunter through a minefield: the single-pass detection probability for mines, the density of "false contacts," and the accuracy with which the mine-hunting sonar and navigational system can locate bottom objects. A series of evaluation exercises by the U. S. Navy Mine Defense Laboratory (then the U. S. Navy Mine Countermeasures Station) provided a wealth of usable data on the AN/UQS-1 and the variable-depth version of the same sonar, the AN/SQS-15. The data were based on a precise optical tracking system at Panama City, Florida, and on a Shoran navigational system employed by the Harbor Defense Unit at Norfolk, Virginia. Later data were obtained by DRL in a series of exercises at Long Beach, California, using Shoran for precise navigation.

1. Single-Pass Detection Probability

a. Lateral Range

A study of single-pass detection probability as a function of lateral range of the mine from the ship's path showed that it decreased with lateral range in a systematic way. The probability of detecting a mine at a given range proved to be proportional to the length of time the target was visible on the sonar scope. The 90° forward-sector scan ($\pm 45^\circ$) then employed with the AN/UQS-1 permitted a mine located 50 yd athwart the ship's path to travel down the scope for nearly 500 yd (using the commonly employed 500 yd range scale). A mine at 350 yd lateral range ($500/\sqrt{2}$) would appear only momentarily at the extreme corner of the scan, and have almost no chance of being detected. On the basis of this geometrical consideration, DRL conducted a trial first at Norfolk, and later at Long Beach through the cooperation of COMINPAC, of the effectiveness of increasing the forward scan sector to 180° ($\pm 90^\circ$), and found that, as predicted, the detection probability remained almost independent of lateral range out to about 300 yards. These tests were described in DRL-A-87, "Effectiveness of 90° and 180° Scan-Sectors for Mine-hunting Sonars," by Lloyd A. Jeffress, February 1955. On the

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basis of these tests it recommended to BuShips that a switch permitting the operator to choose the automatic scan to be employed be installed on MSOs. As a result of this recommendation, MSOs were equipped with a switch that permits the operator to choose the 90° forward sector, or one of three 180° sectors: beam-to-beam, starboard bow to port quarter, or port bow to starboard quarter. The last two scans are employed when the ship is making a pass near the edge of the field and is not interested in looking beyond its boundaries. The use of the 180° scan sector makes it possible to employ a single value for detection probability instead of different values for different lateral ranges.

b. Operator Efficiency

Data on single-pass detection probability showed that it can vary from almost zero for some water and bottom conditions, and some operators, to nearly unity under other conditions. To see what effect the operator's skill had on detection, DRL conducted a series of studies of sonar-operator proficiency, employing a tape-playback system and an AN/UQS-1 scope. The tapes had been recorded during mine-hunting runs made at Panama City and permitted a reconstruction on the sonar scope of the same presentation seen by the operators making the runs. A series of tapes was chosen representing various sonar conditions from very good to very poor, with voice comments on one channel available to the evaluator but not to the sonarman. The sonarman's detection performance and the accuracy of his range and bearing estimates were determined. The results of the tests were issued in DRL-A-116, "An Evaluation of AN/UQS-1 Fleet Sonar Operator Performance," by L. D. Hampton, D. C. Teas, and J. C. Whitesell, 22 January 1957. Briefly the results showed that sonarmen ranged from excellent to poor in their performances. The highest detection percentage was 96 and the lowest 7. The number of false contacts reported ranged from zero for one operator who had a 50% detection score to 53 for another who had a detection score of 71%. One of the best operators had a detection score of 86% while reporting only 8 false contacts. There were 28 mines in the series of tapes. The study found no correlation between performance on the test and operator training, Navy rate, or experience. The authors had the subjective impression that the best operators were more interested and better motivated than the poorest, but no other source of the differences in performance could be discovered.

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2. False Contact Density

a. Observed Values

Ships equipped with the AN/UQS-1 have universally complained that the sonar is incapable of distinguishing between a mine and a great many other targets. When the target is a sizeable object on the bottom, (a NOMBO--non-mine bottom object) only an ultrahigh-resolution sonar, like the AN/SQQ-14 or SHADOW, which bases its classification on shape, can make the needed distinction. However, many ships report that minelike contacts appear on one pass and are not seen on the next, or that dives to investigate the contact at the time it is seen often reveal nothing. It is this type of contact that was referred to as a "false contact" in the report. They have later been dubbed NOETs (Non-Enduring Targets) by the U. S. Navy Mine Defense Laboratory. The frequency with which they occur appears to depend upon water condition, although no obvious correlation has been found. They seem to be echoes from discrete objects, possibly large fish or small schools of fish, gas bubbles, localized turbid spots, turtles, etc. They are similar to one another in being randomly distributed in time and space, and in being generally weaker targets than mines. One study (pp. 27-28 in DRL-A-89) counted the number of appearances on the AN/UQS-1 scope of mines and "false contacts," plotting the percentage of each that appeared n or more times, against n . The curve for false contacts fell consistently below that for mines.

The report includes data from a large number of mine-hunting runs made at Panama City, Florida, and at Norfolk, Virginia. A study of the data revealed that the run-to-run variation in the number encountered per mile followed the Poisson distribution, and that the number per unit of area in the field after a large number of runs followed the same distribution. It was only when the kind of non-random process generated by looking for clusters (i.e., moving the unit of area around so as to include as many contacts as possible) occurred, that the Polya distribution proved to be more appropriate.

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b. Clusters

If we take a plot of sonar contacts accumulated over a large number of ship passages through the field, we find clusters of contacts grouped near one another. If the navigational-sonar accuracy were nearly perfect, the contacts from fixed bottom objects (mines and NOMBOS) would bunch tightly and would be easily identified. With imperfect accuracy, there will be an area of uncertainty-- in the report a circle which would encompass 95% of the contacts from a mine was employed. If we use the area of the circle as our "unit area" and move the circle about on the chart to enclose as many contacts as possible, we locate the bottom objects, but we also enclose clusters of random contacts. It is these that are called "false clusters" in the report, and that follow in their probability density functions, the Polya distribution. The occurrence of clusters containing several contacts is too frequent to fit the Poisson distribution because of the non-random way in which the areas are chosen. The procedure tends to maximize the number of clusters containing many contacts, and to increase the frequency of points in the "tail" of the distribution.

c. The Polya (Negative Binomial) Distribution

The Polya distribution, as mentioned earlier, is obtained by expanding $p^n(1 - q)^{-n}$ and yields the following series:

$$f(x) = p^n + np^nq + \frac{n(n+1)}{2!} p^nq^2 + \dots + \frac{n(n+1)\dots(n+x-1)}{x!} p^nq^x + \dots, \text{ etc.}$$

Each term is the probability that a coin (possibly biased) with a probability, p , of coming heads, and of, q , of coming tails will come heads for the x th time on the $(n+x)$ th toss. The mean of the distribution is nq/p and the variance is nq/p^2 . When $p = q$, the variance is twice the mean, and this is the value which proved to give the best fit to our false-cluster data.

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3. Sonar/Navigational Accuracy

a. Sonar Accuracy

The accuracy with which an operator can report the range and bearing to a sonar contact depends upon a number of factors, some under his control and some not. The combination of errors resulting from non-linearity of the range scan, non-linearity of the x and y amplifiers, poor centering of the display, parallax, improper repetition rate for transmission, poor servo alignment, etc., combine to yield both random and systematic sonar errors. The systematic errors can usually be eliminated in a large measure by proper setting-up procedures and routine maintenance, but there remains a substantial random error in the location of sonar targets. The size of the error is difficult to measure since it is generally confounded with the error in locating ship's position. DRL-A-89 presents data on sonar-navigational accuracy without much success in estimating the two sources separately, although on the basis of data taken at Panama City using an optical tracking system on the beach, and at Norfolk, using Shoran, it concludes (p. 84) that the major source of error with either system is the sonar.

b. Navigational Accuracy

For clustering procedures to be of much use in distinguishing bottom objects from NOETs, precise information about ship's position in the minefield is essential. Both Shoran and SOTS (the Shore-based Optical Tracking System now in use at the U. S. Navy Mine Defense Laboratory) provide the kind of precision needed, as do also several more recent developments in precise navigation. The standard deviations along course or athwart course encountered in the tests reported in DRL-A-89 ranged from about 15 to 25 yards. Since the overall standard deviation is the square-root of the sum of the squares of the two standard deviations taken separately, reducing the standard deviation due to navigation to zero would improve the figure at most by about 40%, if half or more of the overall error is owing to the sonar. Obviously, allowing navigational errors to increase so that they make up more than half of the total will degrade the overall accuracy, and can easily make it intolerable for clustering purposes.

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c. Effect of Error

The effect of sonar/navigational error is to increase the area of a cluster--the area within which contacts from a given mine might be expected to fall. If this area could be reduced to zero, two contacts from different passes through the field would suffice to identify the source as a bottom object (or at least stationary). The larger the area the more chance there will be for NOET contacts to cluster within similar areas and so to look like mine clusters. This, in turn, means the need for more passes through the field to distinguish between NOET clusters and clusters from bottom objects. The report presents data showing the savings of time which can result from improving the sonar/navigational accuracy.

d. Area of Uncertainty

In the report, DRL-A-89, the area of a circle (or ellipse if there is considerable difference between the variance along course and athwart it) which would encompass 95% of the contacts from a bottom target was used in later computations. For a normally distributed collection of errors, this would mean a circle having a radius 2.45 times the standard deviation (and a corresponding sized ellipse). For the errors frequently encountered, a circular distribution is sufficiently precise, and standard deviation between 15 and 25 yd is typical, with the radii of the corresponding 95% circles about 35 to 60 yd, and the areas about 4,000 and 12,000 sq yd, respectively.

B. Prediction

1. Standard Targets

By placing a standard target (in DRL-A-89, a Mk 6 mine moored close to the bottom was used) in or near the field to be searched, estimates of the detection capabilities of the sonar, and the accuracy of the sonar/navigational system can be made. Estimates of the single-pass detection probability and of the standard deviation of the system are made from the returns from the standard target after several runs past it. The report describes how these estimates can be made.

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2. Detection

If we know (or have a reasonable estimate of) the single pass probability of detecting a bottom mine--the quantity called "p" in the report--we can predict the number of runs needed to assure obtaining \underline{n} or more contacts from a given mine. Families of curves, one for each confidence level, 90%, 95%, and 99%, are presented in the report showing the number of runs needed (as ordinate) for a given probability, p, (abscissa) and for a selected value of \underline{n} (the parameter of the family of curves). Thus for a 95% confidence level, and a single-pass detection probability of 0.75 we find that to obtain 5 or more contacts from a mine requires 8 runs; to obtain 8 or more requires 12 runs. To obtain a 99% confidence level for the same detection probability requires 9 runs for 5 or more contacts, and 8 or more requires 14.

3. False Clusters

In making the runs required to reach the desired level of confidence, we encounter NOETs, and after several runs they begin to "cluster"; i.e., to fall close enough to one another to lie within our circle of uncertainty. Another set of families of curves predicts the expected number of these "false clusters" per 100 units of area--the area of the circle of uncertainty being taken as the "unit" of area. For these curves the ordinate is the expected number of false clusters per 100 units of area, the abscissa is the number of runs, and the parameter is the number of contacts, \underline{n} . There is one family of curves each of several values of false-contact density from 0.003 per unit area per run to 0.10. If we assume, for example, a density of 0.05 false contacts per unit area per run we find that after the 8 runs of the previous paragraph we can expect 0.7 false clusters per 100 units of area containing 5 or more contacts. For 12 runs and 8 or more contacts, the value drops to below 0.2.

Working with the two families of curves, those for detection and those for false clusters, we find, of course, that increasing the number of contacts demanded will increase the number of runs required to reach the desired confidence level and that the false clusters increase as the number of runs increases. They decrease, however, as the value of \underline{n} is increased, and the rate at which they

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decrease with n is substantially more rapid than the rate with which they increase with the number of runs. There is therefore a net gain in "classification" as the number of contacts demanded for designating a "cluster" is increased in spite of the increase in the number of runs required. The decision about when to stop is based on the logistics of the situation--time required for hunting vs time required for disposal, availability of divers, etc.

C. Prediction vs Observation

1. Tests of Predictions

The report contains a number of examples of the application of the predictive techniques to actual mine-hunting data. In general both the predicted number of runs required and the predicted number of false clusters agree as well as could be expected with the actual observations.

2. Extensions of Predictions

By employing the prediction techniques described, it is possible to make estimates of the effects changing various parameters. For example, there is a curve indicating the expected improvement in mine-hunting performance which could result from a substantial improvement in the overall sonar/navigational accuracy. The rate of improvement in hunting effectiveness with increased accuracy was so rapid as to indicate the need for a substantial effort to improve sonar/navigational accuracy. Other similar extensions are to be found in the report.

D. COMINPAC TACNOTE 1-58 and 1-60

1. TACNOTE 1-58

Following the issuance of DRL-A-89, COMINPAC requested that Defense Research Laboratory prepare a "cookbook" version of the report for use as a mine-hunting doctrine by the ships of MINPAC. With the approval of Code 463 of ONR, this rewriting was undertaken. In the course of it, a new quantity, "coverage," was developed and a method for assessing it derived by Dr. Ralph Lane, who had

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helped us with much of the earlier statistics. The probability, P , of getting n or more contacts from a mine referred to a mine. The coverage, C , is the probability of getting n or more contacts from all of the mines in the field. The new version also included detailed instructions furnished by the U. S. Navy Electronic Laboratory for setting up the AN/UQS-1 for optimal performance, and specific methods for plotting sonar contacts from Shoran coordinates. TACNOTE 1-58 remained in force until superseded by COMINPAC TACNOTE 1-60.

2. TACNOTE 1-60

This tactical notice superseded TACNOTE 1-58. It was a condensed version of the former and included new material furnished by the U. S. Navy Mine Defense Laboratory on the use of 1-ft triplanes as navigational referents where Shoran was not available for navigation. Experience with the application of the methods of TACNOTE 1-58 indicated that NOET clusters were not the serious problem that they had been in the earlier studies, and much of the material on them was omitted from TACNOTE 1-60.

E. The AN/SQQ-14 and SHADOW

Defense Research Laboratory throughout all of its work on clustering has taken the position that this is a method of desperation, to be employed only when nothing else will serve. The appearance on the scene of two sonars capable of distinguishing between mines and non-mines on the basis of shape rather than target strength alone, the AN/SQQ-14 and SHADOW, have made (or will make, when they become available in numbers) the clustering technique obsolete. The technique is still needed, however, when the AN/UQS-1 is the only sonar available, and water conditions make its performance less than perfect. The statistical procedures described in the report and in TACNOTE 1-58 are still valid and much of the material is relevant to mine-hunting with any sonar.

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III. PRECISE NAVIGATION: ELECTROMAGNETIC

A. Introduction

Because of the importance of precise navigation (more properly, precise piloting) to the success of clustering techniques of mine hunting, DRL with the support of Code 463 of ONR became concerned with the problem of finding a more appropriate system than Shoran. Shoran had the merit of being available, and of approaching the desired accuracy, but it had the serious disadvantage of requiring maintainable beach stations, and therefore, possession of the beach before mine hunting could proceed. What appeared to be needed was a ship-based system operating with unmanned navigational beacons, such as buoy-mounted radar reflectors or transponders that could operate for several days or possibly weeks.

B. The Marine Autotraverse Positioner (MAP)

DRL learned through NEL of the existence of a precise navigational system developed and used by the Scientific Service Laboratories, Inc., of Dallas, Texas. The system was employed for precise ship location in off-shore geophysical surveying, and appeared to have the desired accuracy. The system was called "The Marine Autotraverse Positioner (MAP)." After some discussion with members of the company, DRL consulted with Code 463 of ONR and finally with the cooperation of COMINPAC arranged to install the equipment on an MSO at Long Beach, California, leasing the equipment from the manufacturer. The tests, which were described in DRL Acoustical Report No. 178 of 18 October 1960, indicated that the equipment could provide a considerably higher degree of precision than was available even with Shoran, and appeared to show promise as a navigational system for MSOs. The system as tested was not very well designed for use in the crowded quarters of the CIC space on an MSO, and DRL, in the report, made a number of suggestions for improvements which the company believed could be made without adding seriously to the cost or maintenance.

An equipment incorporating many of the suggestions made by DFL, other made by NEL, and still others made by the company was purchased by NEL for use with their HDU boat. Their experience with the equipment was encouraging, and led to further suggestions for improvement.

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As a result of experience with the MAP and with many of the navigational problems of MSOs, DRL wrote a report, DRL-A-208, "A Proposed Navigational System for MSOs," dated 14 February 1963. The proposed system incorporated many of the features of the MAP with many of the features of the conventional DRA and DRT of the MSO to provide a flexible but reasonably simple overall device which could be used for precise navigation in mine hunting, and also for the usual functions of the DRT. It could also employ radar range-bearing information, and was compatible with sonar-doppler inputs.

Partly on the basis of DRL's report, and partly through consultation with NEL, the Bureau of Ships ordered a third version of MAP. It incorporated many of the suggested new features and many others suggested by the company. The device was to be employed as the navigational system for the AN/SQQ-16 sonar. When delivered, it was installed on NEL's HDU boat and later on the USS CAPE (MSI-2). The equipment was given a Fleet Operational Investigation by OPTIEVFOR and a final report (Project F/0154 FY 64) issued 27 November 1964. The major conclusions and recommendations of the OPTIEVFOR report were as follows:

MAJOR CONCLUSIONS

"It is concluded that:

- a. The Marine Autotraverse Positioner provides navigational information that is superior to that currently available to mine force ships.
- b. Minesweepers equipped with the MAP system can successfully transit a narrow channel if the location of the channel relative to reference buoys is known.
- c. The MAP range and bearing servos are unsatisfactory.
- d. The performance of the MAP digital range circuitry is unsatisfactory.
- e. The reliability of the MAP system is unsatisfactory.
- f. The MAP system capabilities are reduced under environmental conditions that preclude the positioning of master reference buoys or that obscure their location from the radar being employed with MAP.

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MAJOR RECOMMENDATIONS

Commander Operational Test and Evaluation Force recommends that the Marine Autotraverse Positioner Navigation-plotting System not be accepted for service use until the following changes are incorporated and the system re-evaluated:

- a. The range and bearing servos are redesigned and null indicators are provided to alert the MAP operator when either the range servos or the bearing servos are not synchronized.
- b. The digital range circuitry is improved and a monitoring circuit is incorporated that will alert the MAP operator to digital range circuitry malfunctions.
- c. The intensity of the cathode ray tube projector is increased.
- d. The method of centering the cathode ray tube display is improved.
- e. The plotting arm locking screws are replaced with a more reliable locking device.
- f. The method of fastening the plotting arm access doors is simplified and improved.
- g. A monitoring circuit is incorporated to indicate the position of major MAP control switches.
- h. The MAP operation and maintenance manual is improved."

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IV. PRECISE NAVIGATION: SONAR

A. Introduction

The range and bearing accuracy of the AN/UQS-1 sonar are sufficient, when the equipment is in proper adjustment, to permit precise location of the ship relative to prepositioned and recognizable bottom referents. The location of suspicious sonar targets relative to these navigational referents can be plotted with good accuracy. On the basis of these facts, DRL with the support of Code 463 of ONR and with the cooperation of COMINPAC conducted several exercises on mine hunting, using the AN/UQS-1 sonar for navigation. The exercises are described in detail in the following DRL reports: DRL Acoustical Report No. 183, "Four Long Beach Exercises in Sonar Navigation," by L. A. Jeffress, dated 5 July 1961; DRL Acoustical Report No. 186, "Acoustic Transponders (100 kc) for Use in Sonar Navigation," by R. K. Goodnow, dated 5 October 1961; and DRL Acoustical Report No. 204, "Use of Acoustic Transponders with the AN/UQS-1 for Precise Navigation," by L. A. Jeffress and R. K. Goodnow, dated 9 July 1963.

B. Use of Triplanes

The earliest attempts involved the use of triplanes laid along the centerline of the channel to be searched, and at about 200-yd intervals. This permitted seeing two or three triplanes on the scope (using the 500-yd range scale) at one time, and allowed them to be plotted on a transparent overlay. It was soon apparent that a serious difficulty existed in our inability to tell one triplane from another, so that if we lost contact for a time due, for example, to traversing a kelp bed, we were not sure which triplane was now in sight. Another difficulty proved to be that under poor sonar conditions, other bottom objects could be mistaken for a triplane.

The U. S. Navy Mine Defense Laboratory, who assisted in writing COMINPAC TACNOTE 1-60, recommended the use of clusters of triplanes laid along the edge of the channel to be searched. The triplanes were laid in clusters of varying sizes so that the particular cluster seen could be identified.

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Because of the difficulties mentioned above and because MDL was continuing the use of triplanes, DRL explored the use of acoustical transponders instead of the triplanes.

C. Acoustical Transponders

1. The Transponders

For an exercise in February 1961, DRL had constructed a number of acoustical transponders which, in interrogation by the AN/UQS-1 transmission, sent back an extended 100 kc pulse (the frequency used by the sonar). Three different pulse lengths were employed to permit distinguishing one transponder from another. They appeared on the sonar scope as lines, extended in range 30, 60 or 90 yards. They were laid in a sequence A A B B C C A C B A, about 300 yd apart, so that the presence of any two consecutive targets on the scope determined the position of the ship uniquely. Because the response of the transponders was stronger than expected, they were laid along the edge of the field instead of in it, so that their responses would not obscure mines in their neighborhood.

2. Plotting Device

Earlier exercise had shown the importance of having a memory of ship's motion during sonar blackouts due to kelp, etc. Accordingly during the February 1961 exercise, a sonar-repeater, plotting-table was provided. It was simply a laboratory oscilloscope mounted in a table containing a chart drive that could be adjusted to the ship's SOG. The locations of the transponders were plotted on a transparent strip during one pass through the field, and then used to conn the ship and to provide reference points for plotting in mines on subsequent passes. The plotting table was equipped with a compass repeater that allowed the chart to be oriented to offset the effects of set and drift.

Plots of the locations of mines were made both on the sonar repeater, which was located in the Crew's Shelter on the O3 level, and in CIC using Shoran coordinates for location. Agreement between the two sets of charts was excellent.

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During the exercise, it was apparent that the use of the repeater left something to be desired in convenience, and that operating directly from the main AN/UQS-1 scope would have several advantages. Accordingly a new plotting device was constructed to fit over the main scope, where use could be made of the true bearing ring in keeping the chart properly aligned with ship's movement over the ground.

3. Demand Keyed Transponders

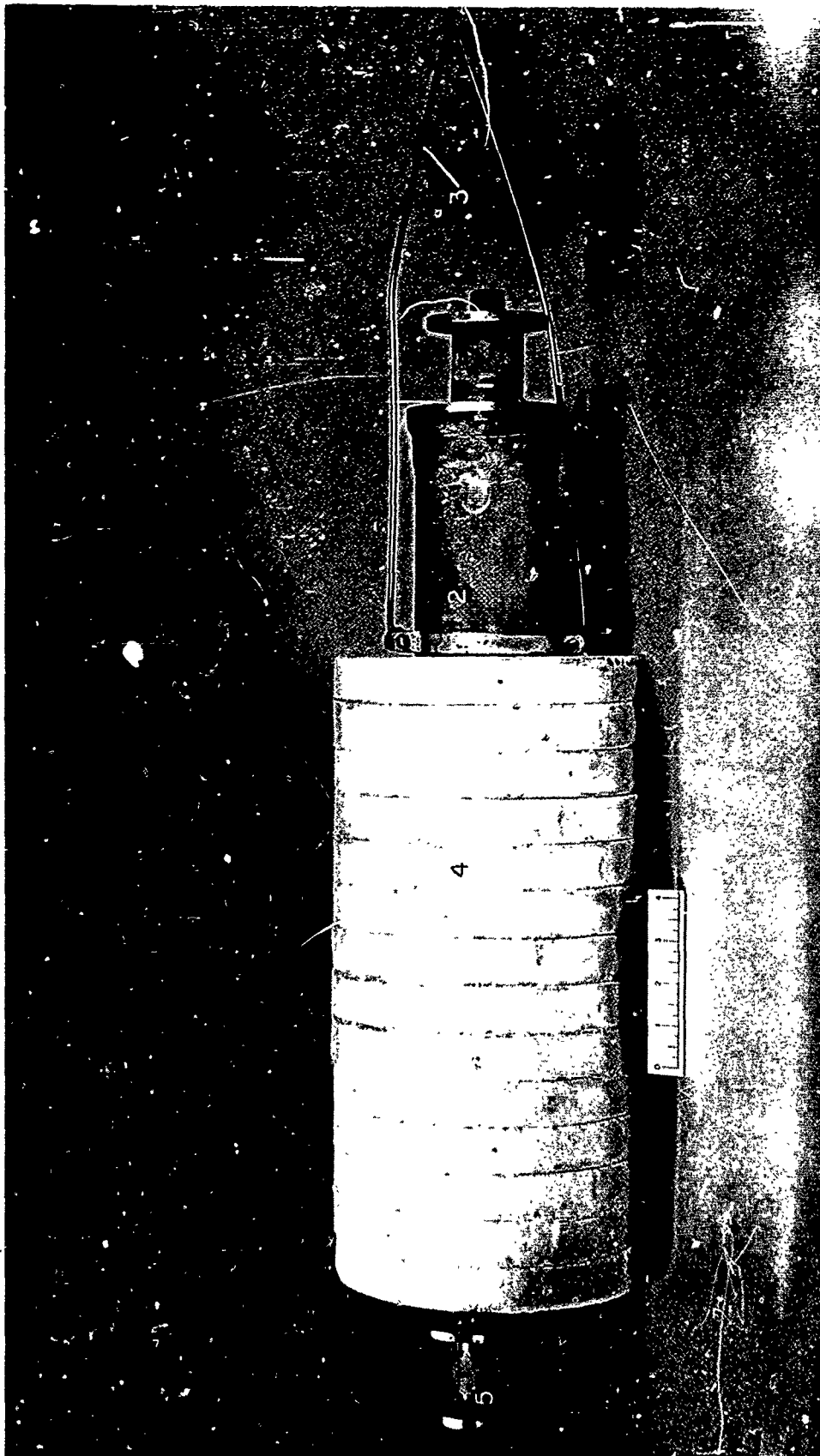
Experience with the 100-kc transponders indicated that they were strong targets which could obscure weaker targets nearby. It was accordingly decided to modify them so that they would reply only when specifically interrogated. This was accomplished by a gate that triggered them only when they received a pulse about four times the normal 1-msec pulse of the AN/UQS-1. A simple attachment to the sonar made the increased pulse length easily available. A photograph of one of the transponders is shown in Photograph No. 72627-179. The receiving transducer is shown at 1 and the transmitter at 5. Flotation is provided by a series of foamed Dylite rings, 4, and the anchoring bail at 3. The transponders are described in detail in DRL Acoustical Report No. 186.

4. Plotter for AN/UQS-1 Scope

The plotting attachment for the AN/UQS-1 scope is shown in Photographs 72627-193 and 194. It is essentially a means for moving a transparent strip across the face of the scope to correspond to the ship's SOG. Means were provided for shifting the strip laterally and longitudinally, and for rotating it to correct for set and drift. Provision was also made to rotate it 180° so as to pick up the ship's return to search after a turn at the end of the minefield. The device and its use are described in detail in DRL Acoustical Report No. 204.

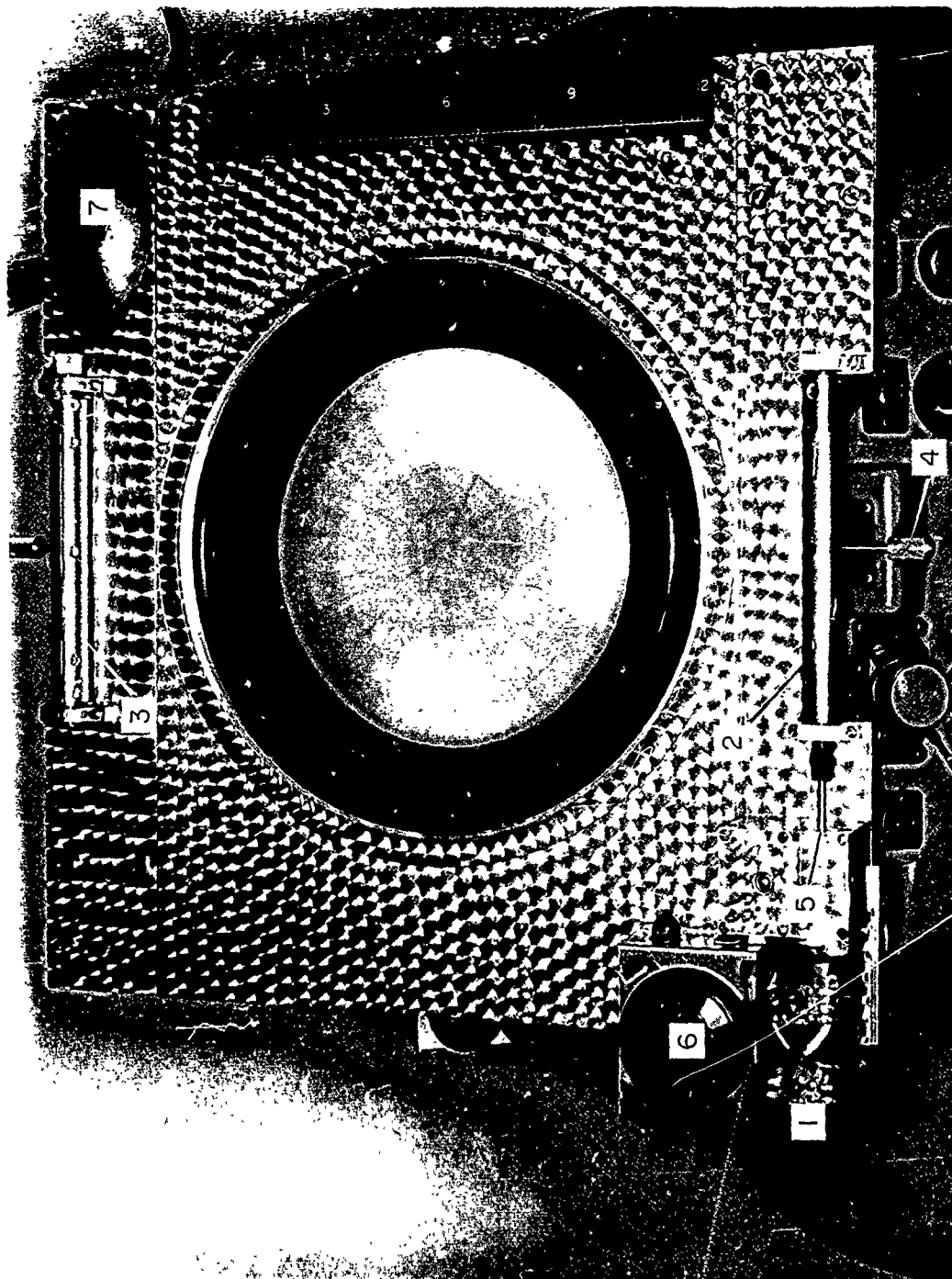
5. October 1962 Exercise

During October 1962, DRL under the sponsorship of Code 463 of ONR and with the cooperation of COMINPAC conducted an exercise at Long Beach, California, employing the plotting device and the new demand-keyed transponders. The exercise

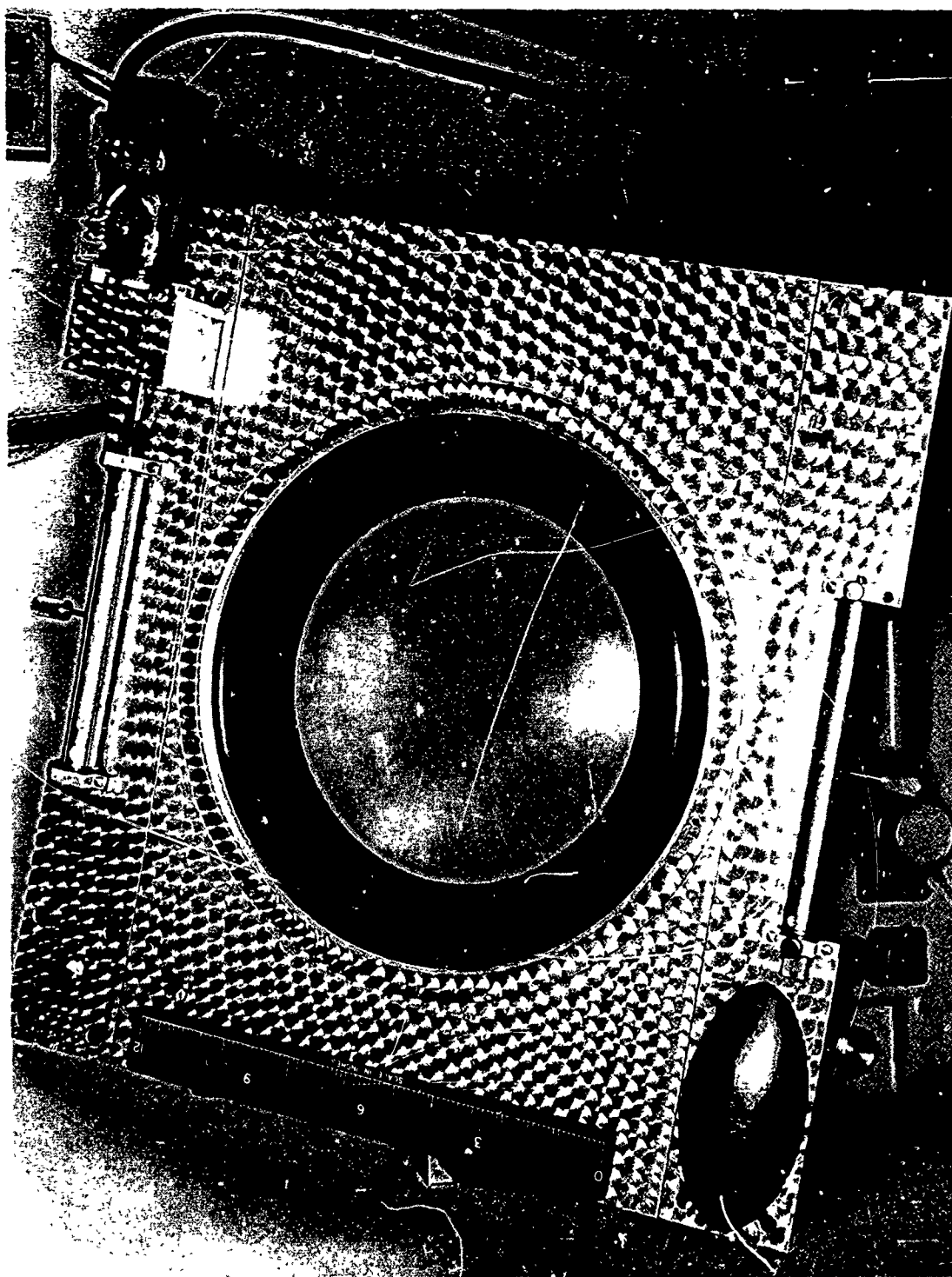


ASSEMBLED 100-kc NAVIGATION-TRANSPONDER

4



PLOTTING DEVICE FOR AN/UQS-1



PLOTTING DEVICE FOR AN/UQS-I

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appeared to establish the practicability of the method. The mine clusters obtained were as tight as those obtained earlier with more elaborate navigational means. The equipment was operated during much of the exercise by ship's personnel, who found it easy to learn to use, and proved so popular that it was borrowed, (along with the transponders) for use for an extended period by one of the other ships of MINPAC.

During the early part of the exercise, the self-sufficient accuracy of the method was rather strikingly demonstrated. The first transponder was laid on the centerline of the minefield by visual fixes from the Long Beach breakwater. The remaining plants were made, using the sonar to measure distances, and the attempt was made to lay them at 300-yd intervals. Subsequent passes through the field failed to confirm the original locations and the transponders appeared to move about in their apparent locations. All of this occurred late on a Friday afternoon. A weekend study of the overlays made clear that the trouble lay in the sonar, that the range sweep must not be linear with range. Later tests of the sonar with a good oscilloscope proved the hypothesis to be correct and after replacing some faulty components in the sonar it was brought into good linearity. Subsequent passes through the field showed the transponders remaining stationary and made possible the accurate plots mentioned earlier.

During the exercise some of the transponders behaved as designed and gave a response only when specifically interrogated. Others responded to the normal 1-msec ping of the AN/UQS-1. One transponder behaved according to design when interrogated from one path, but responded to the 1-msec ping from another path. Examination of the transponders showed that they were performing correctly. It was therefore concluded that probably the location of the transponder relative to the sound-path from the ship could in some cases result in stretching the 1-msec transmitted pulse into a longer pulse at the receiving hydrophone. A study of the geometry of the situation made this explanation plausible.

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V. MINE DISPOSAL

A. Introduction

One of the recurring problems, once you have located a mine and know its position on the bottom with precision, is what to do about it. A buoy 45 yd away, bearing 335° magnetic from the mine, can serve as a point of departure for divers, but unfortunately it is often only a point of departure, and the divers never find the mine. DRL personnel have often had the experience of watching divers on the AN/UQS-1 scope and of seeing them, even divers equipped with the AN/PQS-1, start off in the right general direction and then wander off, missing the target completely. Often with the AN/PQS-1, a clump of shells appears a better target to the diver than the mine, and he will be drawn to it instead of the desired target. Apparently the only way to assure that the diver will find the target you are trying to vector him to is to drop a marker within a few feet of the target, at least within circling line range.

The only alternative to the diver at the present time appears to be a small (?) explosive charge placed near enough to the mine to render it safe or to blow it up. If the distance can be made really small, the charge can be small. The charge appears to vary in mass about as the square root of the distance.

In both types of operation the important consideration is reducing the distance between the mine and the marker (or charge) to a minimum. With the AN/UQS-1 it is often possible to resolve a mine and a marker when they are about 7 ft apart and with the higher resolution of the AN/SQQ-14 this distance can often be as short as about 1 foot. Either distance is close enough for a diver to find the mine in a matter of two or three minutes, but the distance is of great importance in affecting the size of the charge to be employed.

In the course of several exercises concerned with mine hunting, DRL has been involved in the ultimate recovery of the mines. In every case the task has not been easy. We have dropped dan buoys as nearly on the mine as possible from the ship, sometimes with good success, sometimes with large miss distances. We have dropped the dan and told the divers where the mine lay relative to it. We have

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vectored the divers' boat, rubber raft or motor whaleboat, to the mine, using a towed sonar target and the ship's sonar, and whatever means of communication between sonar and the boat could be rigged, from radios to signalmen. The experience is frustrating. You get the boat on the right bearing and watch it approach the mine, giving it last-minute corrections that never quite get carried out, and finally just as the signal to drop is given, the boat has somehow got yards from where it was and the drop is too far off for a quick dive. If the divers go down, they spend an hour searching. If you recover the buoy and try again, you probably do not do much better on the second attempt. Direct communication with the divers would apparently help but has never been available during any of the exercises in which DRL has been involved.

Most of this trouble stems from two sources, inability to communicate with the boat reliably and quickly and inability of the boat to maneuver at the slow speeds needed just at the end of the vectoring operation. The maneuvering of the boat is made doubly difficult by the fact that the tow point for the diablo or other sonar target is forward, and the rudder and propulsion is at the stern, so that the boat tends to pivot around the tow point at slow speeds. The radio-controlled catamaran devised by DRL under the present contract, was an attempt to circumvent these sources of trouble.

B. Radio-Controlled Catamaran

1. Early Versions

The remote-controlled boat went through several versions, which are described along with the final version in DRL Acoustical Report No. 242, "A Remote-Controlled, Mine-Disposal Boat" (U), by Lloyd A. Jeffress, Robert K. Goodnow, and Ervin R. Hafter, 9 June 1965. The early versions were built to test the overall concept, especially maneuverability at slow speeds and while towing a sonar target. Several improvements in methods of control were devised during these early tests made at DRL's Lake Travis Test Station. Several methods of propulsion, such as electric and hydraulic, were either tested or examined and rejected in favor of a standard easily procurable gasoline outboard motor. Standard automobile parts were used where possible for reasons of both cost and availability.

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2. Final Version.

The final version of the boat was built solely to test the concept at sea in operation with an MSO employing its AN/UQS-1 for vectoring. It was hoped that enough could be learned from the exercise to determine whether the concept was sound, whether such a boat would be useful to the Navy mine forces, and what modifications could be foreseen to provide the design of a craft that would be acceptable for Service use.

The boat had to be large enough to be seaworthy in reasonably rough weather, but small enough to stow on the fantail of an MSO, and light enough to lift over the rail by the port-quarter crane of the MSO. It had to have enough speed and endurance to keep station with an MSO while traversing a minefield or moving to a new location, and it had to be rugged enough to survive a reasonable amount of mishandling.

a. The Hulls

The hulls finally employed were fabricated at DRL in the form of aluminum cylinders with conical caps at bow and stern. The bow caps were tilted upwards and truncated to avoid plowing into waves. The hulls are shown in Photographs 3579(01)-26 and 27. (A, Fig. 1 and B, Fig. 2) They were 19 in. in diameter, 12 ft long, and filled with styrofoam. As mounted they were 4 ft apart on centers giving the boat a beam of about 5-1/2 feet. Figure 2 shows the boat in the water. As can be seen, over half of the hull is above the waterline.

b. Propulsion

Propulsion was furnished by an 18-hp Evinrude outboard motor (K in Fig. 2). The longest foot commercially available was employed with a low-pitched propeller. A cylindrical shroud 6 in. long was constructed around the propeller and ended in a longitudinal fin (rudder) along the bottom. The fin was about 4 in. in depth, and furnished rudder action when the propeller was stopped. The shroud provided slightly better thrust than the unshrouded propeller, protected the propeller from damage during loading and off-loading of the boat, and served as protection for divers working near the boat.

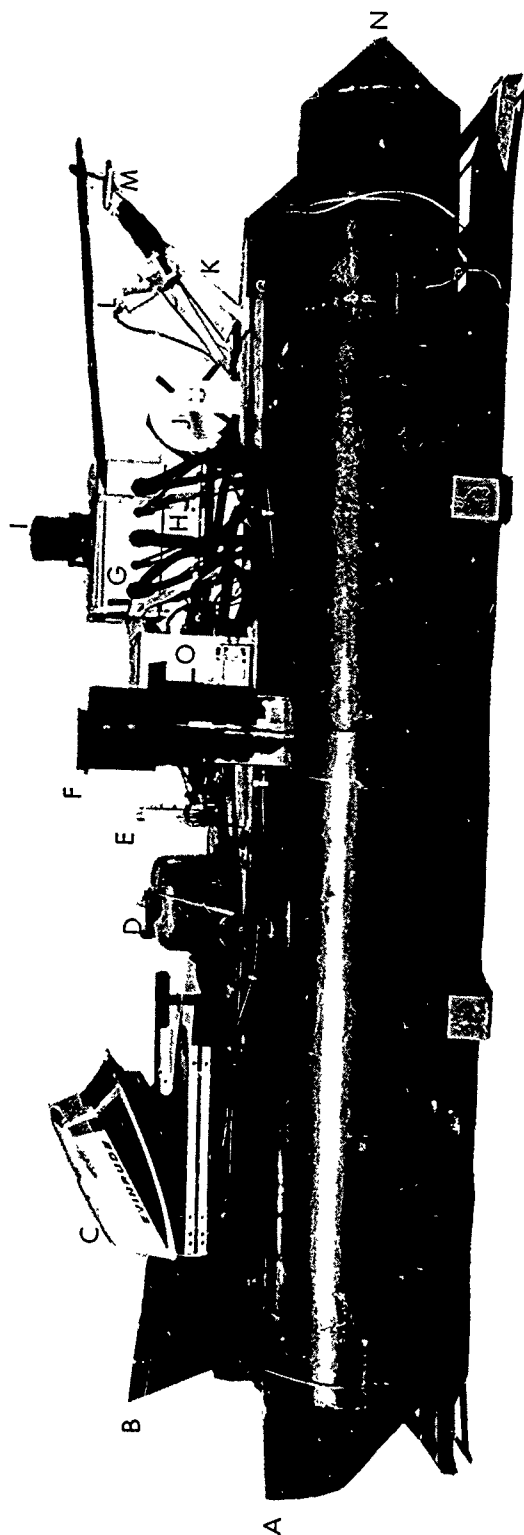


FIGURE 1

PHOTO A

PORTSIDE VIEW OF BOAT

- | | |
|-------------------|---------------------------------------|
| A. BOW CONE | H. STORAGE - BATTERY BOX |
| B. SPLASH GUARD | I. EMERGENCY - VEHICLE FLASHING LIGHT |
| C. OUTBOARD MOTOR | J. WINCH REEL |
| D. GASOLINE TANK | K. ARMS FOR TOWING-EYE SUPPORTS |
| E. STEERING DRUM | L. TOW - TENSION SWITCH |
| F. DAGGER BOARDS | M. TOWING EYE |
| G. RELAY BOX | N. STERN CONE |
| | O. SPEED AND SHIFT CONTROL ENCLOSURE |

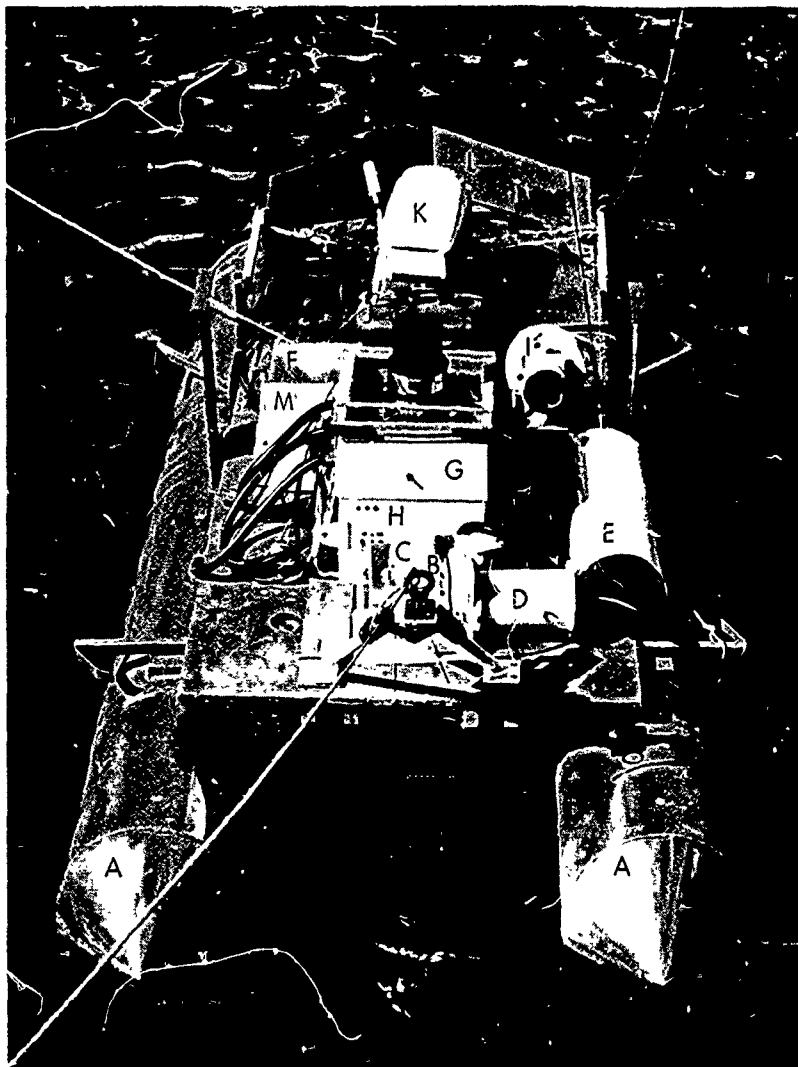


FIGURE 2
PHOTO B
STERN VIEW OF BOAT

- A. STERN CONES
- B. PAD-EYE FOR TOWING
- C. WINCH DRUM
- D. WINCH MOTOR
- E. SUN SHIELD FOR TANK CONTAINING RADIO
RECEIVER AND TRANSISTOR CIRCUITRY
- F. EMERGENCY-VEHICLE FLASHING LIGHT
- G. RELAY BOX
- H. BATTERY BOX
- I. STEERING GEARBOX AND DRUM
- J. GASOLINE TANK
- K. OUTBOARD MOTOR
- L. BOW SPLASHBOARD
- M. SPEED AND SHIFT CONTROL ENCLOSURE

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The motor was capable of driving the boat at speeds in excess of 10 kt even with the crudely shaped hulls employed. With properly configured hulls better speeds could be easily attainable.

c. Radio-Control

Twelve channels of radio-control information were used. They were as follows:

- 1-2 Rudder, Left - Right
- 3-4 Rudder Amidships, Automatic - Manual
- 5-6 Engine, Start - Stop
- 7-8 Speed, Fast - Slow
- 9-10 Clutch, Engage - Disengage
- 11-12 Towing Winch, Up - Down

Each radio channel was provided by an audio-frequency oscillator in the transmitter (Orbit 12 channel) tuned to the frequency of one of the 12 reeds in the receiver (Orbit 12 channel). Vibration of the reed produced a series of contacts that charged a small capacitor and triggered a transistor switch. This in turn operated a relay that provided the power for subsequent operations. The radio receiver and the associated transistorized circuitry were housed in a waterproof aluminum tube painted white and provided with a sun shield to reduce absorption of heat when the equipment was operating in the sun (E in Fig. 2, Photograph B). No difficulty was experienced with the transistorized circuitry due to temperature.

The automatic control of the rudder proved a valuable feature. When the boat was being sent out on a bearing, the control was left in "manual" and small rudder adjustments could be made to correct for set; but when the boat was at a range of 100 yd or more, seeing the position of the rudder was not possible and, especially in turns, the self-centering feature was often used. When in "automatic" the rudder returned to amidships after each release of the left-right control.

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d. Safety Interlocks

Limit switches were provided on the speed, gearshift, and steering controls and, in addition, an interlock prevented shifting the clutch at high motor speeds.

e. Fail-Safe Device

To prevent the boat from running away in the event it got beyond radio range or the radio-control failed for other reasons, a time delay relay circuit was provided. This operated whenever the boat did not receive a command of any sort within a selected period of time (usually 30 seconds). Failure to receive a command permitted a relay to drop out and resulted in slowing the motor speed to idle, and shifting the clutch into neutral. Subsequent commands restored normal operation.

f. Towing Winch

A winch capable of raising and lowering a 50-lb biconic reflector (diablo) was provided. It was powered by an automobile starter motor operating from the 12-V storage battery. A pair of metal fingers provided a circuit which was closed by the metal diablo and served as a limit switch for upward travel of the tow. The tow line passed over a roller which maintained a switch in its open position when there was a strain on the line. When the strain was removed, as when the reflector touched the bottom, the switch closed and operated a flashing light which could readily be seen even at long range. An emergency-vehicle, rotating flashing red light was employed for easy visibility.

g. Steering

The steering cables factory-furnished with the outboard motor were employed in steering. The cables encircled a drum which was driven by an automobile window motor. Limit switches on the drum prevented overdriving.

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h. Gearshift

Forward and neutral operation of the clutch of the outboard motor was provided by a gearbox attached to the remote shift factory-furnished with the motor. No provision was made for reverse, and it did not prove to be necessary, although it would have been a convenient feature at the time of bringing the boat alongside the ship.

After a series of tests at Lake Travis, it was decided that the boat was ready to be tested at sea, and arrangements were made with COMINPAC for two weeks of operation at Long Beach, California.

3. Long Beach Tests

COMINPAC made available the USS GALLANT (MSO-489) for the two weeks from 11-22 January 1965. DRL's boat was taken to Long Beach on a commercial small boat trailer pulled by a station wagon, and lifted aboard ship by a crane. A faulty weld in the lifting bridle permitted the boat to fall about 8 ft to the dock. The resulting minor damage was repaired by ship's personnel and shipyard welders, and the boat was ready for use the following day. It was given a series of tests in the basin adjacent to the pier and proved to be operational. The remaining tests were made in the vicinity of a bottom mine outside of the Long Beach breakwater. Most of the tests were conducted with the ship anchored about 200 yd from the mine.

a. Vectoring the Boat

(1) The AN/UQS-1 Sonar

The AN/UQS-1 sonar has a range resolution of approximately 2 yd and a bearing resolution which at 100 yd yields a resolution of about 2 yd also. These figures are borne out by the findings of the exercise, that when the sonar blip representing the biconic reflector (diablo) and that representing the mine fused into one, the targets were within 7 ft of each other. In practice it is possible to do better than this by taking advantage of ping-to-ping integration.

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The bearing of the mine is determined as accurately as possible by reducing the receiver gain and transmitted power until the target shows up as a very small spot. The operator uses the cursor to pinpoint the target in bearing, averaging its position as it jumps around slightly from ping-to-ping. He then sends the vectored target out on the bearing line represented by the cursors (which is kept very faint in brightness to avoid smearing). As the diablo is approaching the mine, the operator estimates its rate of approach (visually) and delays his order to drop until the two blips have been fused for a few seconds. By utilizing the ping-to-ping integration to improve bearing accuracy and by making a good estimate of the time required by the diablo to travel the distance remaining after the images have fused, the operator can make the drop come closer than the 2 or 3 yd predicted from the sonar resolution. This technique is only possible, of course, if the operator's control of the boat is sufficiently precise and prompt.

(2) Controlling the Boat

The boat was controlled by radio from the bridge. The sonarman transmitted his orders to the boat-control radio operator via the 27 Mc, giving at first a bearing and range to the mine. The radio operator brought the boat to approximately that bearing and to a range less than that of the mine. When the sonarman had picked up the towed target he then vectored it out to the mine by indicating the distance to go and whether the boat should move to the left or right (as viewed from the bridge). He attempted to have the boat on the correct bearing and proceeding out on that bearing whenever the distance to go was less than 20 or 30 yd, and kept announcing the distance to go to the radioman so that there was no last minute surprise when the order to drop was given.

This type of operation had been attempted by DRL on a number of previous exercises where it was desired to mark the sonar contact as accurately as possible, but usually met with little success because of the lack of maneuverability of the boat and the delays in getting the commands to the boat's personnel. In the present exercise it was possible to make the final approach to the mine at speeds well under 1 kt and to make the small adjustments in direction needed for accurate vectoring. At these speeds, less than 2 ft per second, the error due to the radioman's reaction time becomes negligible.

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One obvious and frequently made suggestion is that the sonarman be given the radio transmitter so that he controls the boat without the need for a "middleman." The only thing to be gained by this would be a fraction of a second in response time. Against it are several arguments. The sonarman has his hands fully occupied keeping the bearing cursor properly aligned, and "riding" the gain and transmit power controls. Having the radioman behind the sonarman where he too could see the scope would overcome this difficulty but it would leave a major one, that the radioman needs to see the boat in order to determine how it is heading and the appropriate maneuver to produce the desired bearing change. This need becomes even more essential if the first pass misses the target, and it is necessary to bring the boat around for a second pass. Finally the radioman needs to see whether, after the drop order has been given, the diablo is actually on the bottom (the signal light flashing). If it is, and the sonarman has indicated that the drop was a good one, he needs to release the diablo line from the winch and drive the boat off, or to keep the boat in the proper position for use by the divers.

(3) Marking the Target

During the present exercise, dropping the diablo on the mine was intended to simulate dropping an explosive charge near the mine, or marking the mine for recovery or disposal by divers. The diablo line was made of polypropylene and was buoyant. It was planned to use 10 or 15 ft more line than was required to reach bottom. This line remained on the drum of the winch after the diablo had been dropped. In the event that the drop was unsatisfactory, the diablo could be lifted and replaced by another vectoring operation. If the drop was satisfactory, the remaining line was payed off the drum and the divers used the (supposedly) floating line to find the diablo and measure the miss distance. The first attempt to employ this procedure showed its weakness. The line did not have sufficient buoyancy to withstand the bottom currents which were present during much of the exercise, and vanished from sight.

The disappearance of the diablo line on the first drop of the exercise served to emphasize several facts about vectoring. First, that divers need to have targets marked for them rather accurately. The divers searched the

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bottom where the drop had been made without finding either the diablo or the mine. The next morning (the drop had been made too late in the day for further operations) another diablo was dropped on the cluster of targets that now showed up on sonar. This time the diablo line was buoyed with a small float. When the divers returned, they reported finding the first diablo, the mine, and a third diablo with no line attached. It proved to have been lost by the USS ACME during an earlier exercise. When the three diablos had been brought up, the sonar picture simplified to a single target, the mine. The divers reported that the first diablo was 20 ft from the mine, and the second, 24 feet. Subsequent drops made during the remainder of the day missed by 12, 25, 5, 7, and 40 feet. The last drop was made after losing the mine on sonar due to the presence of a large school of fish in the area of the mine.

b. Subsequent Operations

After the first full day of operation, with DRL personnel operating the sonar and the radio transmitter to the boat, the operation was turned over to the ship's personnel, with a sonarman on the sonar and a radioman controlling the boat. The miss-distances for the day were 15, 15, 6, 4, 20, 0 (diablo touching the tailplate of the mine), 12, 36, 12, and 50 feet. The 4-ft miss was after a second drop. The first attempt appeared to the sonarman to be off, and the diablo was hoisted and moved to the new location. The large miss-distances toward the end of the day were due to schools of fish swarming around the mine. We continued to be plagued by schools of fish during the remainder of the exercise, and for that reason were unable to make as many measured drops as had been planned.

c. Use of Transponders

During several periods toward the end of the exercise, the schools of fish became so troublesome as to make it impossible for the sonarman to track the diablo. On these occasions, one of DRL's navigational transponders (see DRL Acoustical Report No. 204) was tied to the diablo line. By taking advantage of its demand-key feature, the sonarman could interrogate the transponder when necessary for identification. Lengthening the AN/UQS-1 pulse from the normal

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1 msec to 4 msec would cause the transponder to reply. Subsequent drops resulted in miss-distances of 20, 10, 15, 2, and 20 feet.

The transponders had been designed for navigational use, and were intended to be anchored a few feet above the bottom and to be buoyant. They were awkward objects to use in towing, and were therefore employed only when water conditions made their use imperative. A similar transponder, but with its housing designed for towing, would have been a welcome improvement on both the diablo and the navigational transponder. The tendency of the diablo to serve as a sea anchor caused it to stream well astern of the boat except at very slow speeds, and seriously limited the speeds with which the boat could be driven when the diablo was in the water. A transponder designed for towing, possibly with a separate battery pack to serve also as anchor, should improve both the ease and speed of vectoring and the reliability of the operation under adverse water conditions.

4. Santa Rosa Mine Recovery Exercise

a. Background

During the course of the Long Beach exercise, the diving officer, who was to be involved in the MINEX at Santa Rosa during the next two weeks, was so impressed with the accuracy of the vectoring that he suggested the possibility of using the boat during the recovery phase of the Santa Rosa exercise. Later conversations with the CO of the ship involved, USS DYNAMIC (MSO-432), and with COMINDIV 91, led to the agreement to leave the boat at Long Beach for use during the recovery phase of the Santa Rosa exercise. Accordingly, the CO of the DYNAMIC, her operations officer, and two enlisted men, a radioman first and an ETN third, rode GALLANT during the final day of the Long Beach exercise. After a short training session, they took over the sonar and the boat control. Since now the primary purpose of the day's work was the training of the personnel who were to use the boat during the Santa Rosa exercises, rather than the gathering of additional data, no dives were made to actually measure miss-distances. Instead, the sonarman from GALLANT served as observer and watched operations from the sonar stack. His previous experience made it possible for him to

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estimate miss-distances reasonably well, and most of the drops made by the new crew, as he estimated them, were within the 7-ft resolution of the AN/UQS-1 scope.

b. Maintenance Training

Previous commitments made it impossible for any of the DRL staff to be present during the Santa Rosa exercise. Mr. Goodnow, however, remained in Long Beach over the weekend to give detailed instructions on maintenance and trouble-shooting to the personnel of DYNAMIC. He also provided them with spare parts, including window motors, gearboxes, etc., and a set of schematics of the various circuits. No difficulties arose during the Santa Rosa recovery operation with which the Navy personnel were unable to cope.

c. Results of the Santa Rosa Recovery Operation

The exercise pointed up again the necessity for getting markers close to the objects marked, especially when they are not mines. If, as has often been the case in the past, the ship finds a minelike sonar context but is unable to mark it closer than 20 or 30 yd, the diver is likely to be unable to find the object responsible for the contact. Even using his AN/PQS-1 and being told that the contact lies at such a bearing and range from the buoy, he is likely to miss the designated contact. The usual source of trouble is the presence of other targets which sound minelike on his AN/PQS-1 and which draw him away from the originally designated contact. Many times we have watched on the AN/UQS-1, seen the divers start off in the right general direction, and then be drawn off to investigate some promising contact--a large sea snail, or a pile of shells--instead of the contact selected by the ship's sonarman. Communication with the diver while underwater would often help, but placing the marker within a few feet of the desired contact appears to be the best method and requires the least amount of bottom time. Obviously, the same order of accuracy is necessary if the "marker" is to be a small, delayed-action explosive charge.

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5. Future Design

DRL believes that the boat has demonstrated its usefulness. Even if it were never employed to place an explosive charge near a mine, it would be a great use to the mine forces in peacetime. Every MINEX leaves the bottom strewn with mines and other valuables which divers have been unable to recover because the objects were not accurately enough marked for them to find. The availability of such a boat would make recovery operations much quicker and less expensive.

In DRL Acoustical Report No. 242, DRL makes a large number of specific recommendations for improvements in the boat, but stresses strongly the importance of keeping it simple and making use insofar as possible of stock items--readily procurable automobile parts (such as window and convertible-top motors and hydraulic systems), standard batteries, standard outboard motors, etc. The recommendations for improvements to the boat are in accord with the recommendations made in a letter to COMINDIV 91 ltr CMD91-ELA:ce Ser 011-65 of 19 Feb 1965. A portion of the letter is included as Appendix A of DRL-A-242. Appendix B is a list of recommended details including specific circuits for employing standard radio transceivers instead of the Citizen's band model airplane radio control used in the present boat.

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13. ABSTRACT This report summarizes over ten years of work on problems in the field of mine countermeasures. It deals with problems of clustering--of distinguishing between mine contacts and non-mine contacts on the basis of the accumulation of sonar contacts from them. Another portion of the report deals with precise navigation, using the AN/UQS-1 sonar with triplane and with acoustic tran- sponders as navigational referents. A final portion of the report deals with the design and performance of a radio-controlled catamaran for marking the position of sonar contacts or for placing a destructive charge near the mine.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Acoustical Transponders						
AN/UQS-1						
Clustering						
False Clusters						
False Contacts						
MAP (Marine Autotraverse Positioner)						
Mine Disposal						
Mine Disposal Boat						
Mine Hunting						
Precise Navigation						
Radio-Controlled Boat						
Remote-Controlled Boat						
Transponders						

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those

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13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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IN REPLY REFER TO:

5513
Ser 43/
7 May 2010

From: Chief of Naval Research
To: The University of Texas at Austin, Applied Research Lab,
P.O. Box 8029, Austin, TX 78713


Subj: MANDATORY DECLASSIFICATION REVIEW

Ref: (a) SECNAVINST M-5510.36
(b) UT ARL ltr of 5 Nov 09

Encl: (1) Final Report on ONR Contract Nonr-3579(01), Problem
1: Study Mine-hunting Techniques (NR 240-014) (U)

1. In accordance with reference (a), a declassification review has been conducted as requested by reference (b) of enclosure (1). This document is hereby downgraded from CONFIDENTIAL to UNCLASSIFIED and is approved for public release with unlimited distribution. However, all classified references associated and listed in this document must be removed prior to release, since those classified references may not have been reviewed and approved for declassification.

2. You may contact Mr. Derrick Shack (ONR 43) at 703-696-1499 or by email at derrick.shack@navy.mil for any questions regarding this matter.


NEVIN P. CARR, JR.
Rear Admiral, U.S. Navy

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